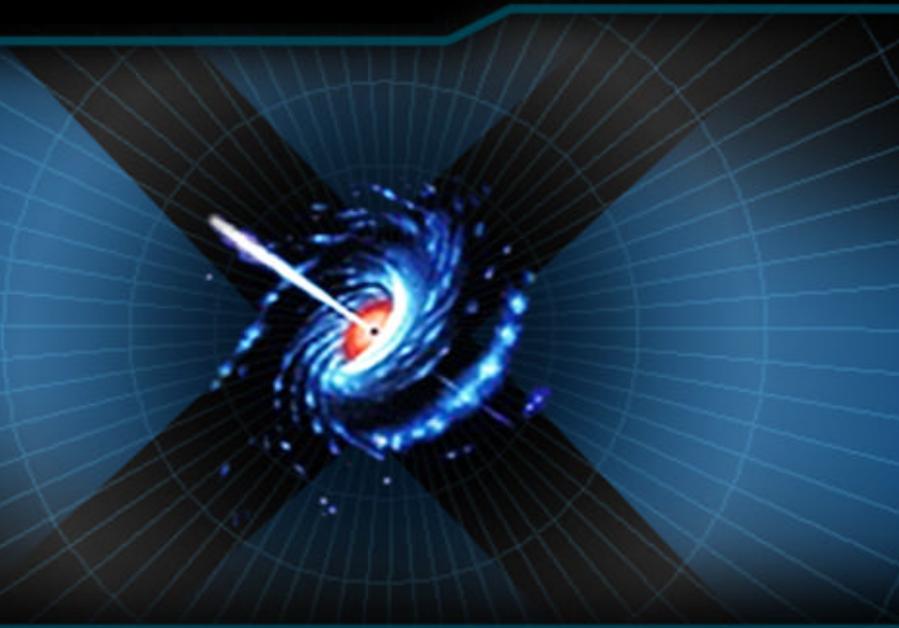


Constellation

The Constellation X-ray Mission



▶▶ Hard X-ray Telescope

Fiona Harrison (Caltech, IPT lead)

on behalf of the HXT Technology Team

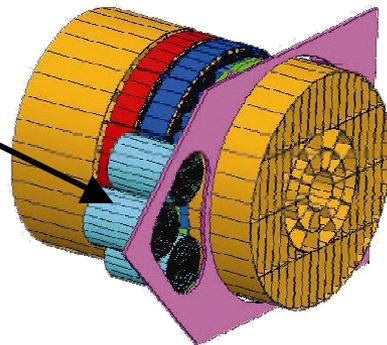
*Participating institutions: Columbia, DSRI, GSFC,
LLNL, MSFC, SAO, U. Brera*



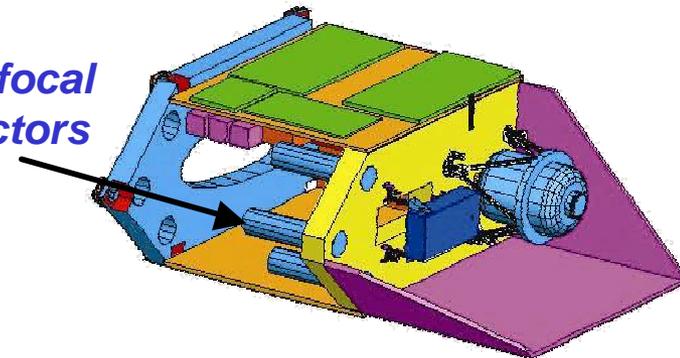
Hard X-ray Telescope Overview

- The HXT supports SXT observations by providing measurements of continuum emission above 10 keV
- HXT continuum sensitivity is designed to match SXT line sensitivity
- Three grazing-incidence multilayer-coated mirror modules on each observatory focus onto three shielded position-sensitive solid state detectors
- All HXT modules are co-aligned with the SXT

*3 HXT
mirrors/observatory*



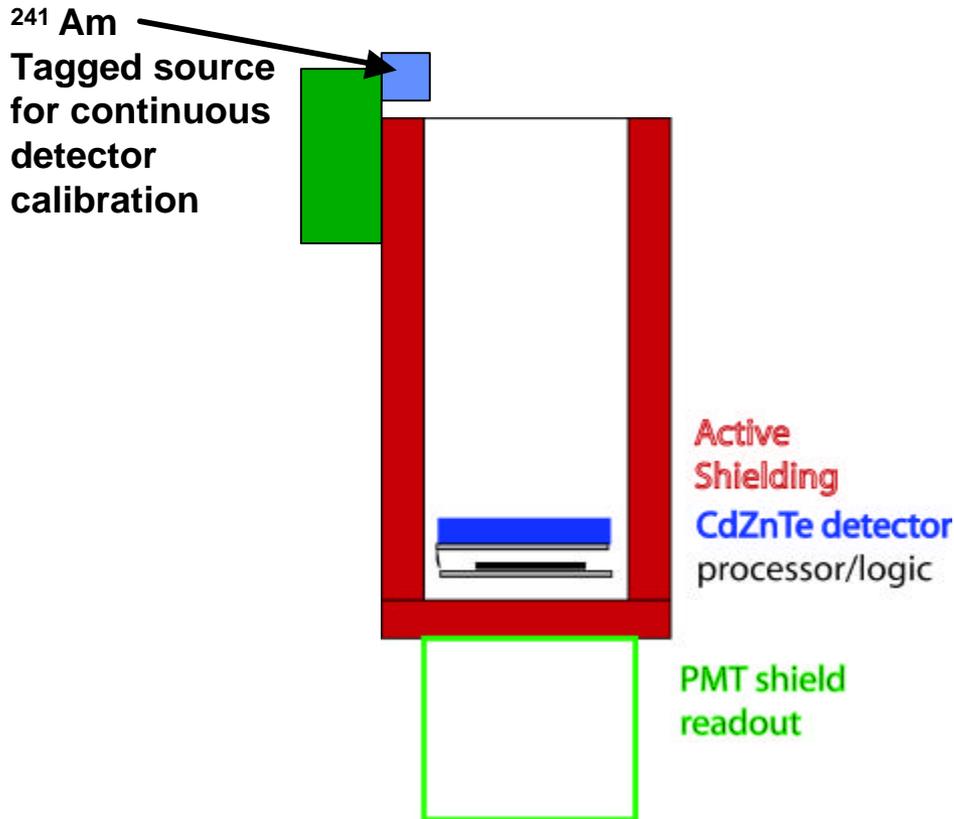
*3 shielded focal
plane detectors*



HXT Requirements Per Observatory

HXT Performance Requirements		Trace to Top-Level Mission Requirements
Bandpass	6 - 40 keV	Allocation of mission TLRD bandpass to HXT
Spectral resolution	10	Meets > 10 keV mission requirement
Angular resolution	≤1 arcmin HPD	Meets mission angular resolution for >10 keV
Signal/Background	>1 for T < 2 x 10 ⁴ s	Meets mission sensitivity requirement for > 10 keV
FOV	≥ 8 arcmin	Meets mission FOV for > 10 keV
Mass	151 kg	Current engineering estimate
Derived HXT Mirror Requirements		Derivation
Focal Length	10 m	Provides shallow graze angles for high energy
Diameter	40 cm	
Collecting Area	139 cm ² each mirror	Allocation for effective area requirement
Derived HXT Detector Requirements		Derivation
Pixel Size	500 micron	Corresponds to 10 arcsec, over samples by a factor 6
Number of Pixels	24 x 48	2 hybrids per focal plane
Quantum efficiency	0.9	Allocation for effective area requirement
Operating Temperature	-15 to -5 C	Meet spectral resolution requirement

HXT Focal Plane – Overview



Detector:

Solid state CdZnTe or CdTe pixel detector coupled to low-noise, low-power custom ASIC

Shield:

CsI or BGO, thickness ~ 1.5 cm
For 30" HPD, plastic-Pb laminate possible

Focal plane module (1 of 3/observatory)

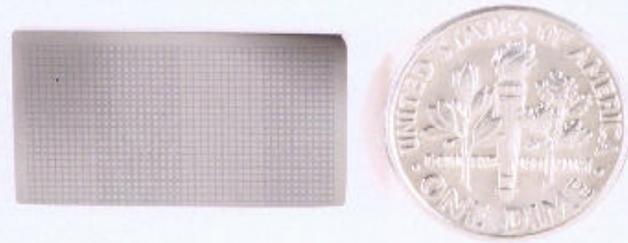
HXT Baseline Focal Plane Parameters

Parameter	Description
Sensor Material	CdZnTe
Architecture	Pixel detector/ASIC readout
Dimension	2.4 x 2.4 x 0.2 cm
Bits/photon	48
Max count rate	50 cts/s/pixel, 200 cts/s/module
Typical countrate	5 cts/s/module
Time resolution	10 microseconds
Shielding	Inorganic scintillator (CsI/BGO)
Thickness	2 cm

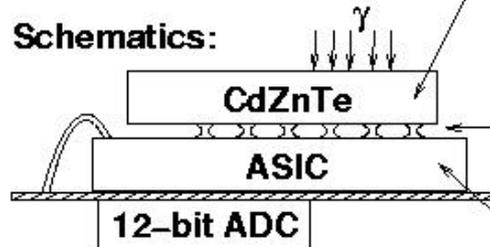
Acknowledgement:
Hubert Chen (grad student, CIT)

Detector Profile

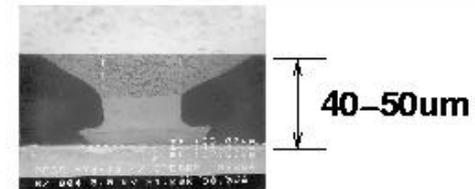
CdZnTe:
single crystal, 13.0 mm x 23.7 mm x 2.0 mm
Anodes: 24x44 pixels, 498- μ m pitch
30- μ m gaps, (468- μ m)² Pt contacts
Cathode: monolithic Pt



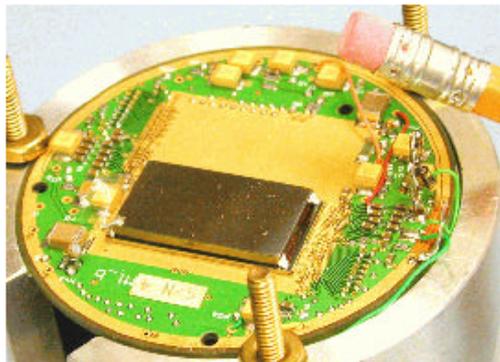
Schematics:



Flip-chip bonded
with stud bump and
conductive epoxy bonds



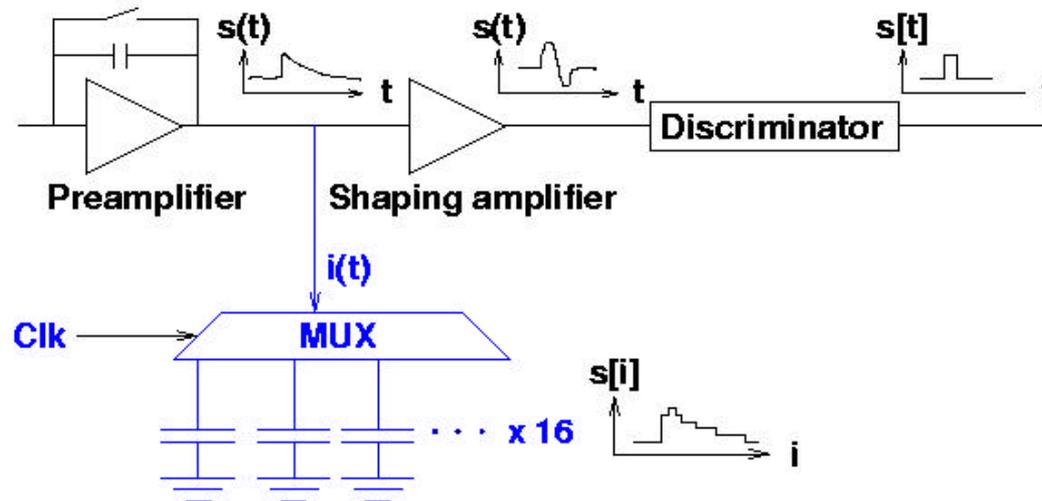
Custom, low-noise,
low-power ASIC readout,
flip-chip bonded



Square sensor area formed by two detectors
with minimal dead area in between

Optimized for operation at 0 C

HEFT VLSI Readout---Special Design



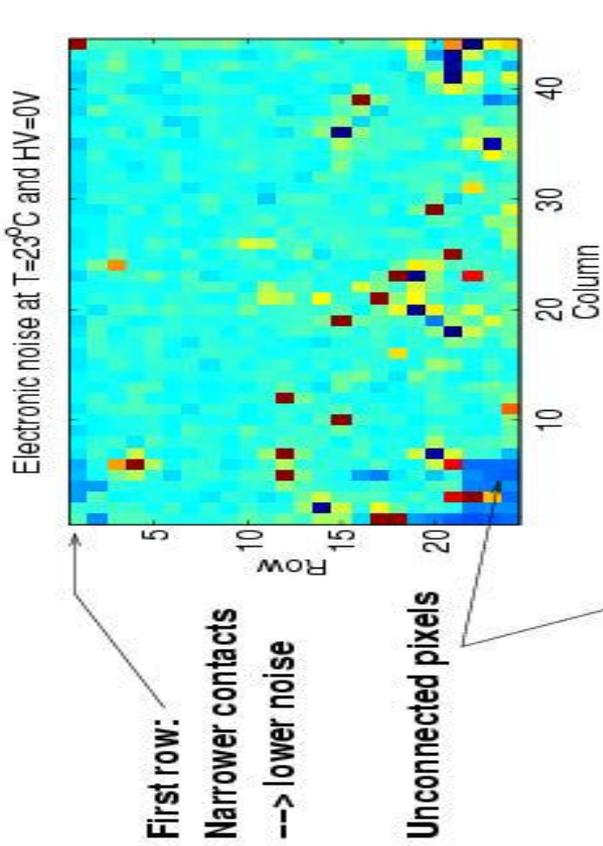
Shaping and peak detection circuitry replaced by
a bank of 16 switch capacitors

Continuous capturing of preamplifier output

Pulse height recovery done off-chip by digital processing

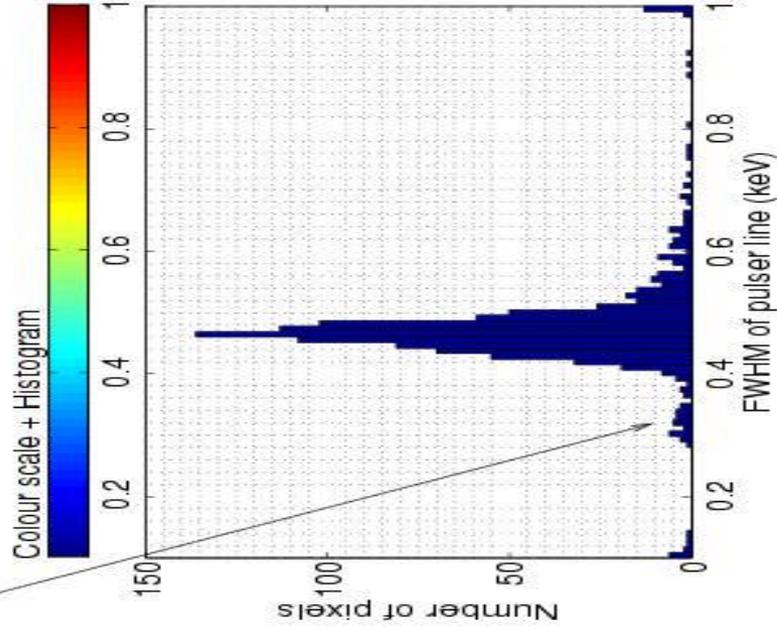
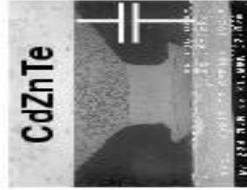
Purpose: Power reduction: 250 uW/pixel \rightarrow 50 uW/pixel

Characterization--Electronic Noise

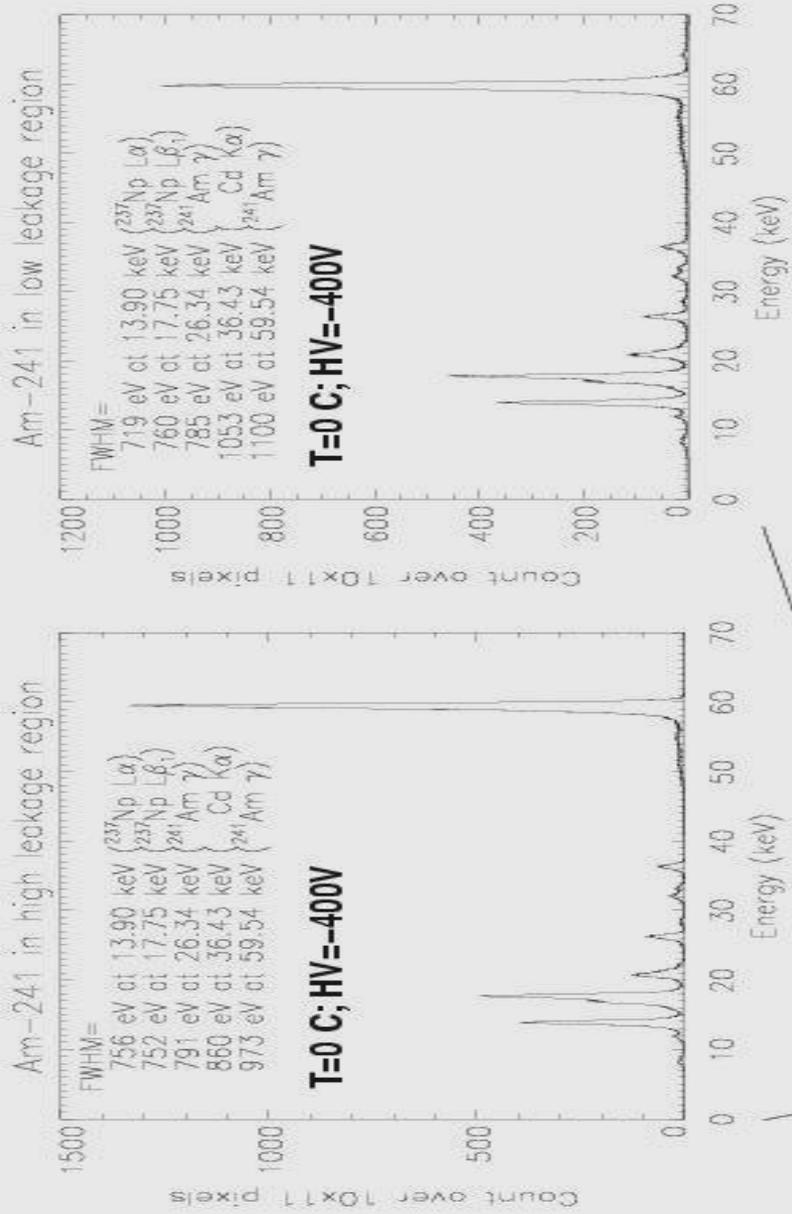


On-chip pulser at each pixel
simulates 75-keV spectral line.

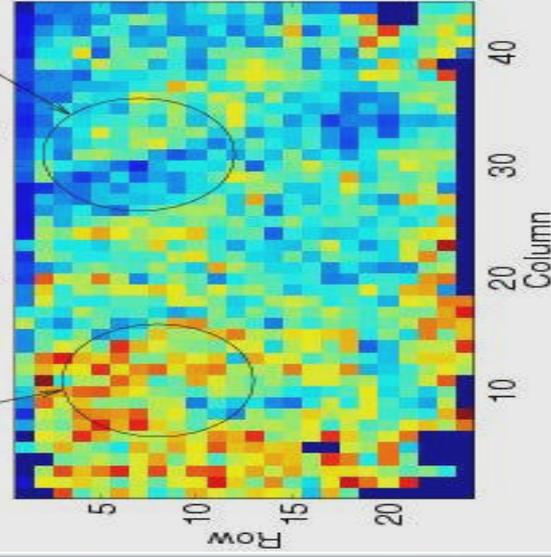
Thermal noise dominated by
input capacitance between
anode contacts and ASIC



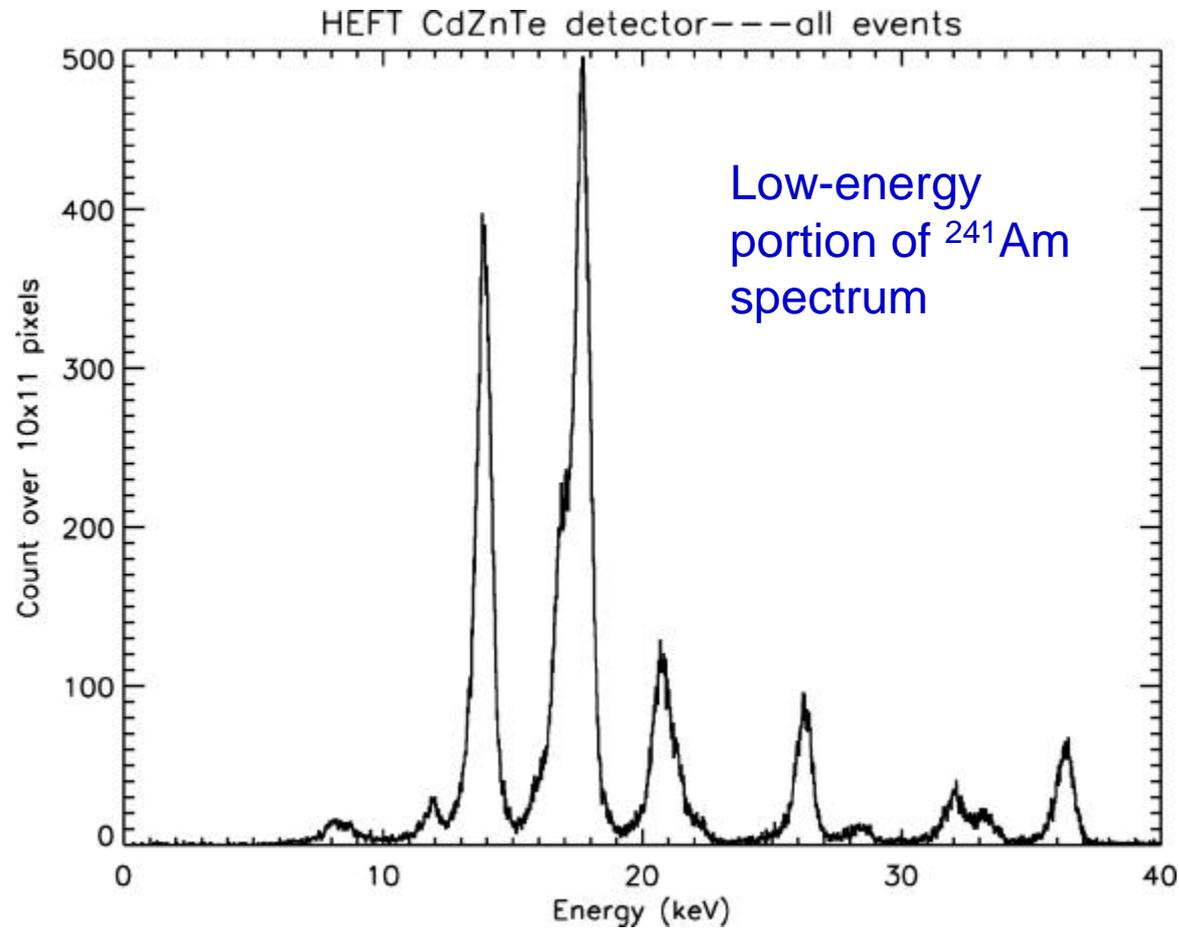
Characterization--Spectral Resolution



Am-241 collimated within circle
 of 10 pixels in diameter
 Both spectra include all events
 triggering 1 or 2 adjacent pixels (>90%)

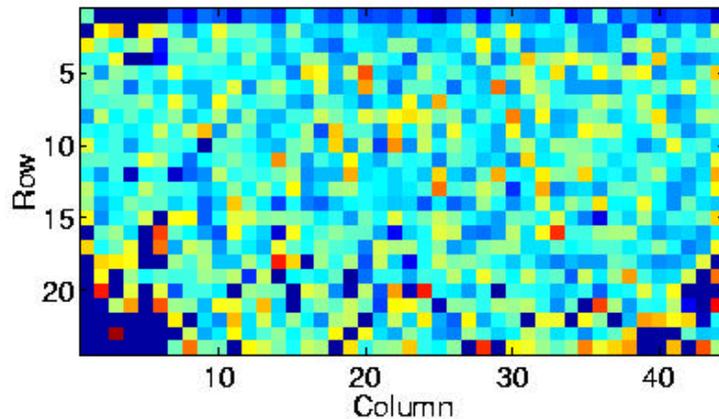


Low-energy line widths dominated by
 electronic noise
 High-energy line widths dominated by depth effect
 Leakage not an issue at 0 C



Characterization--Count Rate

Count rate

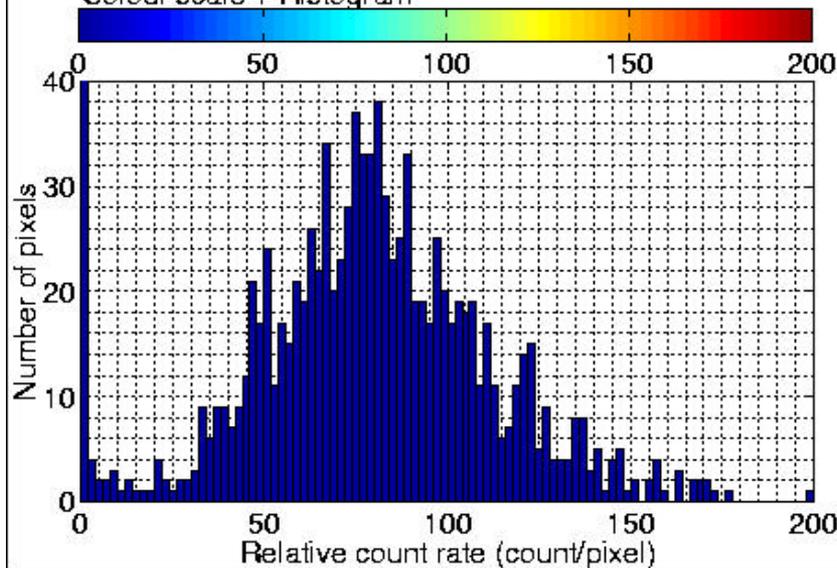


High variation in count rate,
with variation \approx mean

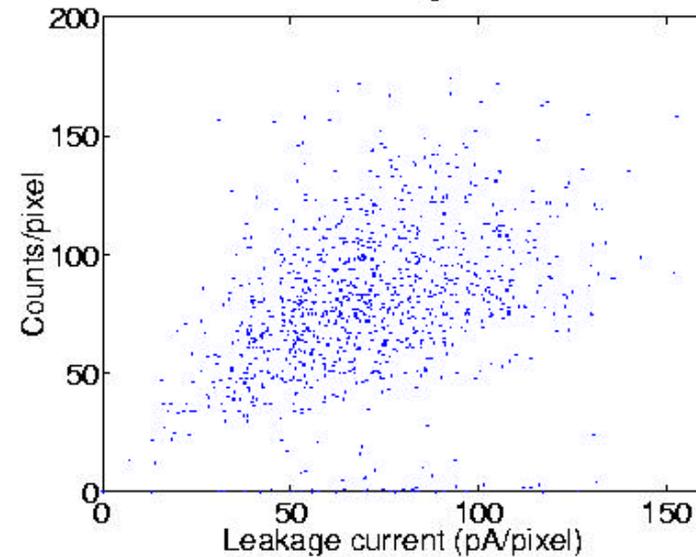
Conjecture:
non-uniform electric field
→ variation in pixels' 'effective area'

Very weak correlation with leakage current

Colour scale + Histogram



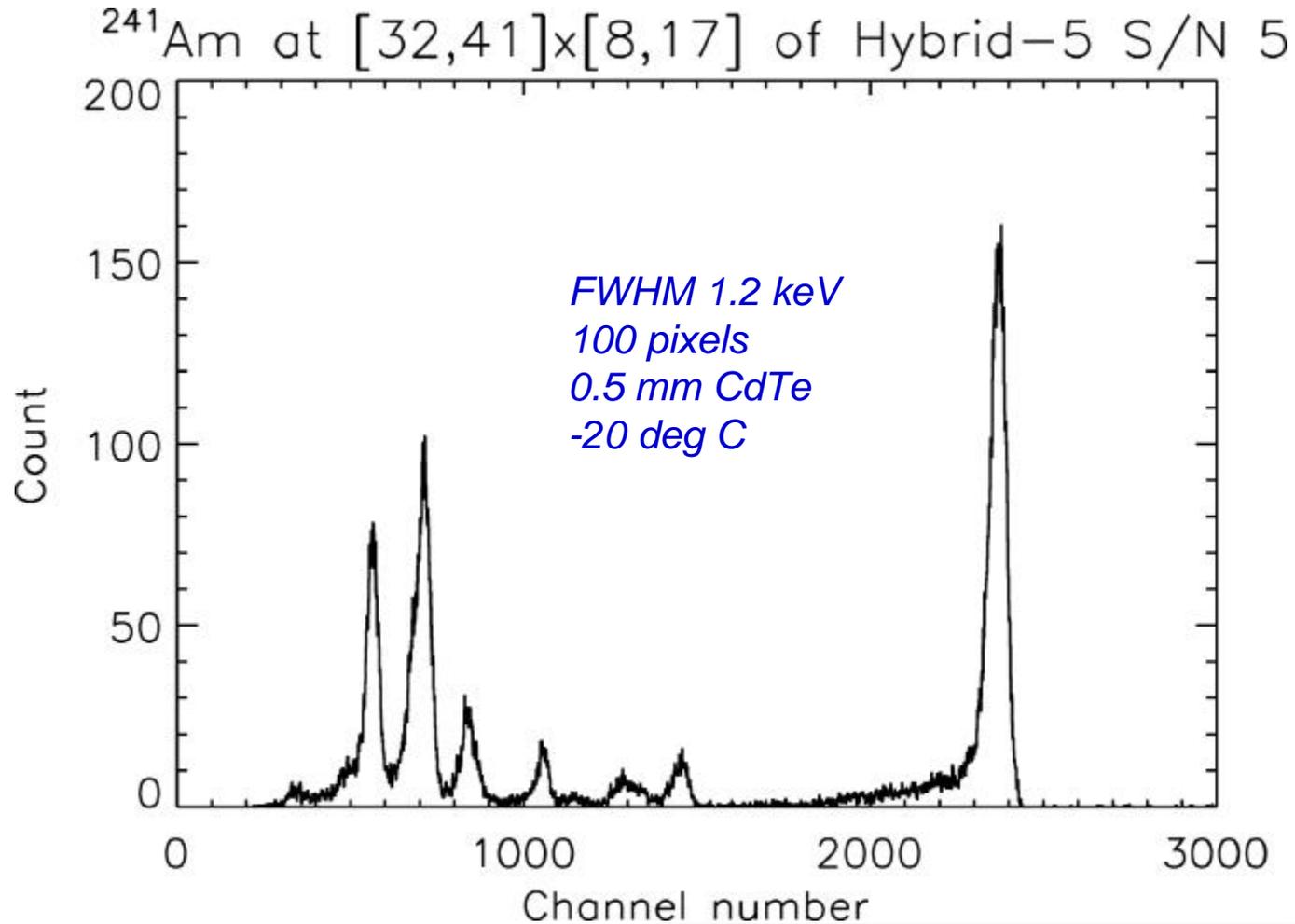
Count rate-leakage correlation



CdTe Sensors on HEFT ASIC

Collaboration with Tad Takahashi, ISAS

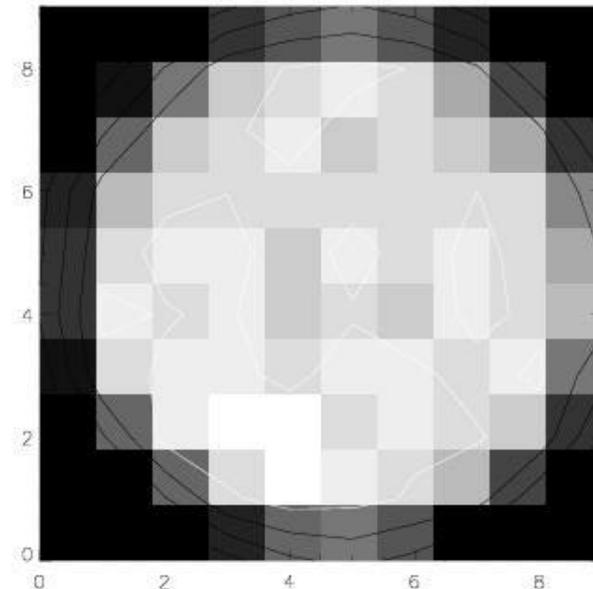
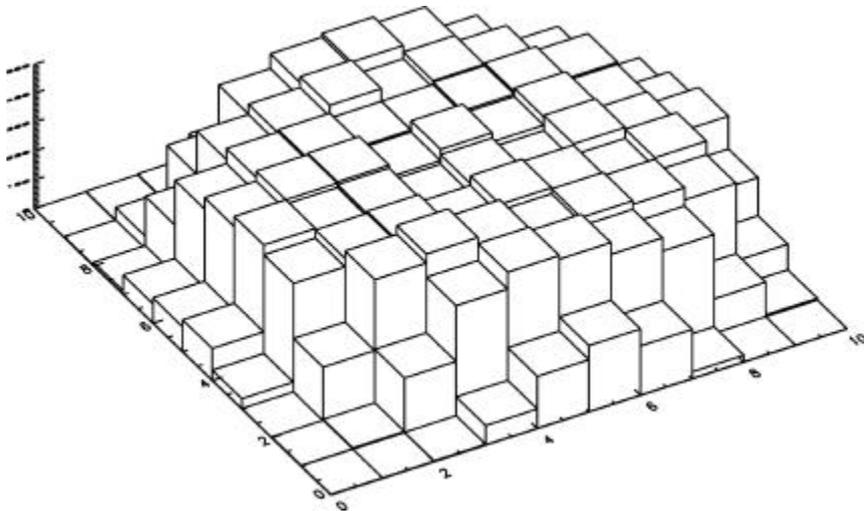
0.5 mm CdTe stud bumped to HEFT ASIC with underfill



CIT/ISAS CdTe Hybrid

Very uniform countrate - variations are consistent with Poisson fluctuations

Circular aperture - illumination with
60 keV gamma-rays. Countrate distribution.



HXT Technology Development Roadmap Summary – Optics

	Technology Selection Prototype		Engineering Prototype
	Glass – Replica Surface	Nickel	Selected Technology
Shell thickness	0.4 mm	0.1 - 0.11 mm	Parameters TBD
Segments/shell	24 (6 azimuthal, 4 axial)	1	TBD
Multilayer	W/Si	W/Si, Iridium	W/Si
Focal length	10 m	10 m	10 m
# Shells	9	6	TBD
Shell diameter / length	10, 22 and 40 cm / 50 cm (P + H)	15 (1 shell) , 28 cm / 43.6 cm	Span full radius range in design
Goals	<ul style="list-style-type: none"> ▪ Demonstrate 30” HPD resolution with replica shells ▪ Demonstrate coating on replica surfaces ▪ Demonstrate required throughput 	<ul style="list-style-type: none"> ▪ Demonstrate HPD for thin Ni shells ▪ Demonstrate internal ML coating technique ▪ Demonstrate required throughput 	<ul style="list-style-type: none"> ▪ Thermal/vacuum test for stability and robustness of components ▪ Demonstrate performance for representative shells covering entire radius range ▪ Mechanical/vibration test for stability, and to establish isolation requirements
Timeframe	Q2 FY04 -- Q1 FY05	Q2 FY04/Q1 FY05	Q2 FY05
Technology Gates			◆

HXT Focal Plane Budgets

	@ 10 keV	@ 40 keV	
Detector FWHM energy resolution (eV)			
<i>Tot Estimated contributions:</i>	720	860	
--Readout noise/pixel (FWHM)	550	550	measured
--Leakage current	200	200	measured -5 C
--Charge trapping	40	350	measured
--Pixel charge reconstruction	450	520	estimate
Requirement	1000	4000	
Margin (%)	28	78	
Detector threshold			
<i>Tot Estimated contributions</i>			
Thermal readout noise + leakage (8 sigma)	1100		measured
Systematic noise (clocking, etc)	4500		engineering goal
Requirement	5600		
Margin (%)	6		
Detector background			
<i>Tot Estimated contributions @ 40 keV</i>	60" HPD	30" HPD	
Activation	9×10^{-5}	9×10^{-5}	
GCR prompt	3×10^{-6}	3×10^{-6}	
Aperture/collimator scatter	3×10^{-5}	3×10^{-5}	
Requirement (cts/s/cm ² /keV)	$<2 \times 10^{-4}$	$<8 \times 10^{-4}$	
Margin (%)	simulation uncertainties are larger than margin for 60" for 30" HPD requirement is 3 sigma (est uncertainty) above requirement		

Detector Technology Roadmap Summary

Demonstration Prototypes		Flight Prototype
Sensor	CdZnTe & CdTe	TBD
Format	8 x 8 pixels	24 x 48
ASIC	Redesign of HEFT chip for low threshold	Full-size version of prototype
Pixel size	0.5 mm	0.5 mm
Goals	<ul style="list-style-type: none"> ▪ Demonstrate low threshold for redesigned chip ▪ Evaluate low-energy performance; QE and resolution for two materials 	<ul style="list-style-type: none"> ▪ Demonstrate threshold for full-sized chip ▪ Qualify packaging approach ▪ Demonstrate in radiation environment
Timeframe	Q2 FY05	Q1 FY06
Technology Gate	◆	

HXT Detector Development Schedule

